GLASGOW NATURALIST Vol. 23 Part 4 pp.36-45 (1999)

ALGAL COMMUNITIES IN GLASGOW STREAMS POLLUTED BY DOMESTIC SEWAGE EFFLUENT

NAITHIRITHI T. CHELLAPPA[1]

Division of Environmental and Evolutionary Biology, Graham Kerr Building, University of Glasgow, Glasgow G12 8QQ

[1]Present address : Departamento de Oceanografia e Limnologia Universidade Federal de Rio Grande do Norte, Natal-RN 59.014-100, Brazil

INTRODUCTION

The impact of nutrient enrichment on the changing biotic nature of running waters is well documented and has been shown to be important in the distribution of aquatic algal communities (Denisegar, Austin & Lucey, 1986; Leland & Carter, 1985; Round, 1981; Whitton, 1975). The present study formed part of a wider examination of the effects of pollution, on the plant and animal communities in streams North of the Glasgow conurbation (Turner & Barr, 1989).

This study compares the seasonal changes in structure of the natural algal communities at contrasting polluted and unpolluted sites on two streams. Communities are described using a species diversity index. Species richness and chlorophyll a are estimated for phytoplankton, epilithon (= on the surface of stones) and epiphyton (= on the surface of plants). Differences in community structure between the four sites are related to water quality parameters, particularly with respect to pollution.

DESCRIPTION OF SITES

Glazert water is 9.5km long and rises at Haughhead (Figure 1). It flows in a southerly direction to join the Kelvin upstream of Kirkintilloch. Pollution in the Glazert Water arises from the Lennox Castle Hospital, which discharges an organically rich effluent. Nailworks Burn, which joins the Glazert Water about 4km from its souree has high levels of ammonia, chloride and especially iron which contributes to the pollution of the Glazert Water downstream. It is also polluted by acid pickle rinse water. The Glazert Water was sampled at two sites, upstream of the Nailworks Burn (GW1) (National Grid reference, NGR NS 619 783) and downstream (GW2) (NGR NS 633 771).

The Allander Water is 13km long and flows off the Kilpatrick Hills in a South-easterly direction to join the Kelvin below Milngavie. The major cause of pollution in this river is the discharge from Milngavie sewage works. The Allander Water was sampled at an upstream site 8km from the sewage works (AW1) (NGR NS 538 768) and at a polluted site (AW2), 2km below the source of pollution (NGR NS 575 729). Table 1 presents information on the catchment area and discharge for the two streams covering the period of study.

MATERIALS AND METHODS

Samples were taken monthly from October 1984 to June 1986. On each occasion temperature and dissolved oxygen were recorded. Sampling was done simultaneously and between 9.00-10.00 a.m. covering a distance of 20km. Water samples for chemical analysis and plankton quantification were collected in 1 litre polythene bottles. Immediately on return to the laboratory, pH was recorded and 5 day Biological Oxygen Demand incubations set up. Water for chemical analysis was filtered through Whatmans GF/C glass microfibre filters, and analyses of nitrate, ammonia, phosphate and silicate were all completed on the day of sampling. Analytical techniques followed those of MacKereth *et al.* (1978). Samples of stone and vegetation for measurement of epilithic and epiphytic communities were taken and transported to the laboratory in wide mouth glass jars. At all sites the bed of the stream was stony. Preliminary studies of the epipelic algal community using the sampling method of Eaton & Moss (1967) and Happey-Wood *et al.* (1988) showed it to be negligible and the algal productivity rate low: therefore it was not sampled further.

Phytoplankton samples were concentrated by sedimenting 1 litre of water in a measuring cylinder. After the supernatant had been removed the residue was made up to 25ml and sedimented again in a counting chamber for enumeration and species identification under a Zeiss inverted microscope. Results are expressed as cells l^{-1}. Epilithic algae were carefully scraped from 30mm^2 area of stone in triplicate. The slurry thus produced was made up to a known volume, carefully mixed and the cells in an aliquot counted using a compound microscope. Epiphytic algae were removed from the supporting vegetation with dilute HCl, following the method of Tippett (1970). Identifications were according to Desikachary (1959), Anagnostidis & Komarek (1990), Hustedt (1930), Lind & Brook (1980) and Prescott (1951). Species diversity was calculated according to Shannon & Weaver (1949) from Log_{10} data, species richness according to Margalef (1958) and a qualitative comparison of the species composition of the four stations was made using Jaccard's coefficient of similarity (Morgan, 1987).

The measurements of chlorophyll *a* for each community were made following the recommendations of Riemann (1980) and Marker *et al.* (1980). Water samples were taken from four sites of Glasgow streams (AW1, AW2, GW1 and GW2), and the pigment analyses were performed on the same day. The plankton from 1 litre of water was concentrated by filtration onto Whatmans GF/C microfibre filter; the slurry scraped from a 30mm^2 area of stone was used for the epilithic community and epiphytes were removed ultrasonically using the method described in Tippett (1970). The ultrasonic treatment was found to be very efficient (85%) except for a few interfering detrital materials. Final volume was brought up to 10 ml before extraction with methanol. Chlorophyll was extracted in absolute methanol and acidification was carried out to obtain phaeopigment. Magnesium carbonate solution was used to neutralize the acid effect. A one hour extraction period was maintained throughout the study. The calculation of Lorenzen (1967) was used to obtain the values of chlorophyll *a* and phaeopigment, expressed as $\mu g\ l^{-1}$ for phytoplankton and cm^2 for epilithic and epiphytic algae.

Statistical analyses were performed using Minitab (Ryan *et al.* 1976). Product moment correlation was carried out between environmental variables as well as species diversity,

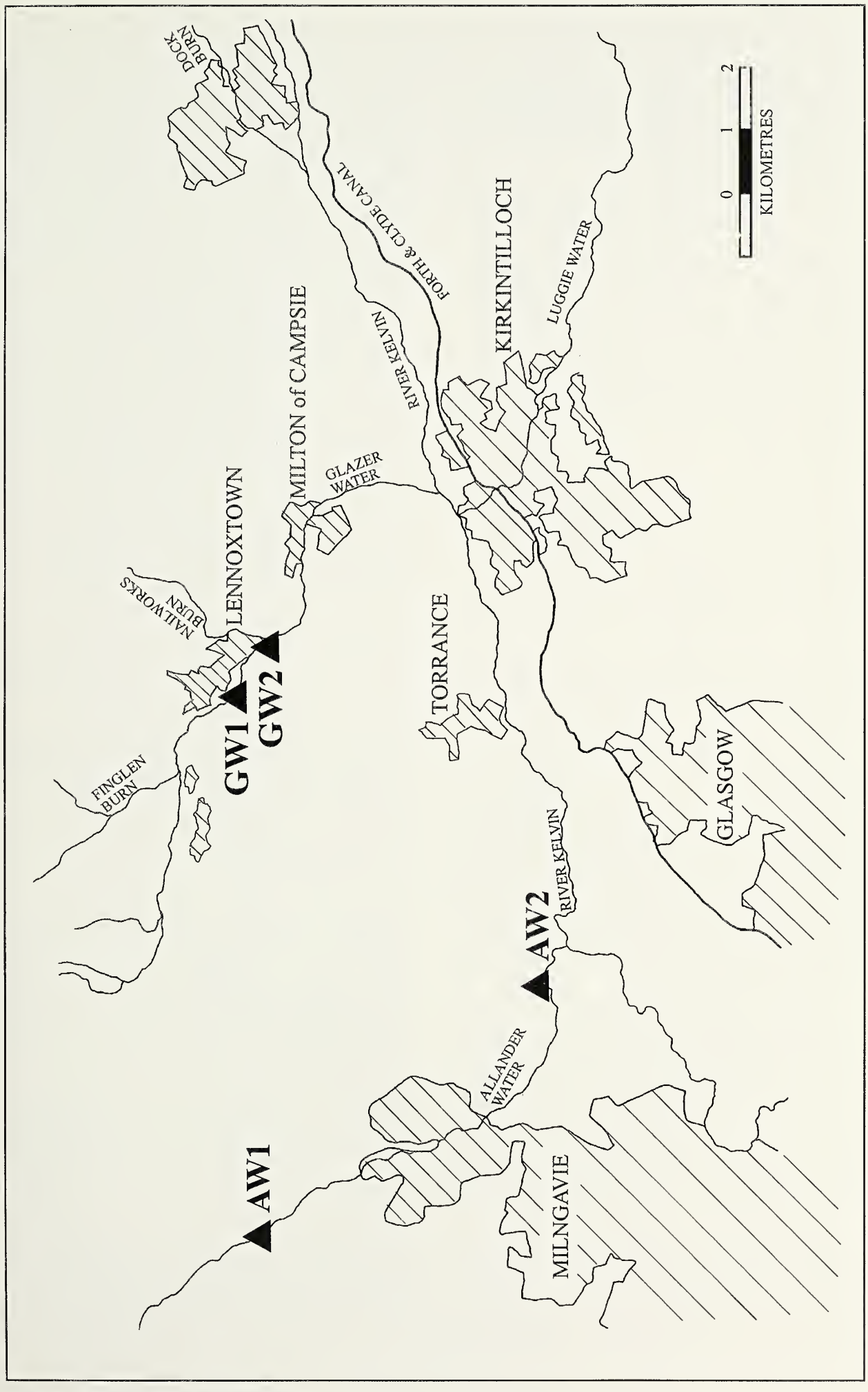

Fig. 1 Location map of sampling sites.

Table 1. Catchment area and flow characteristics of Allander Water and Glazert Water. AW1 is situated 8 km upstream and AW2 2 km downstream from the gauging station. GW1 is 2 km and GW2 1 km upstream from the gauging station

	Allander Water		*Glazert Water*	
	Discharge ($m^3 sec^{-1}$)	**Mean water velocity ($m sec^{-1}$)**	**Discharge ($m^3 sec^{-1}$)**	**Mean water velocity ($m sec^{-1}$)**
Long term average	1.2	0.36	1.7	0.025
Maximum recorded	53.8	8.3	71.2	6.47
Minimum recorded	0.006	0.005	0.05	0.02
1986 Values: average	1.8	0.54	2.5	0.37
maximum	45.2	6.9	54.1	4.9
minimum	0.062	0.05	0.141	0.06
Catchment area (km^2)	32.8		51.9	
Width of stream (m) at gauging station	6.3		8.6	

species richness and chlorophyll *a*. Multiple regression analysis was performed between all independent variables and chlorphyll *a* for phytoplankton, epilithic and epiphytic algae.

RESULTS

Environmental parameters

Temperature differences between stations were small, while seasonal variation was very marked, ranging from sub-zero temperature in winter to 14.5°C in summer. Allander Water pH ranged about neutrality with means of 7.14 and 7.03 respectively for AW1 and AW2, whereas Glazert Water was significantly acidic (pH means of 6.89 and 6.76 respectively for GW1 and GW2). In both streams pH was slightly more acidie in winter than in summer.

At the unpolluted sites AW1 and GW1, dissolved oxygen varied from minimum values of 7.5-9.5 to maximum values of 13.5-14.4 mg l^{-1}. At the polluted sites AW2 and GW2, dissolved oxygen was considerably reduced with values as low as 1.7-2.4 and maximum values of only 6.25-7.3 mg l^{-1}. At AW1 oxygen saturation was 90-100% throughout the period of sampling. At GW1 oxygen saturation was 90-100% throughout most of the study period but was reduced to 42-53% during the late summer of 1985. At AW2 and GW2 oxygen saturation was 40-50% in winter and fell to 16-23% in summer.

At the clean sites of AW1 and GW1 the mean values of Biological Oxygen Demand were 3.6-3.8 mg O_2 l^{-1} compared with downstream sites (AW2 and GW2) where BOD reached as high as 8.8-10.1 mg O_2 l^{-1}. BOD was strongly influenced by thermal conditions in both Allander and Glazert Waters.

Nitrate nitrogen concentrations at polluted sites (AW2 and GW2) were highest during winter, which may be due to leaching from farm land; and in the spring, prior to stream algal increase in unpolluted sites (AW1 and GW1). The decline through the spring and summer was gradual at all four sites, with the lowest concentrations being recorded in late July. The rise in nitrate over the winter corresponded to minimum biological activity and maximum flow rates (Fig 2a). Increase or decrease of nitrate did not show any correlation with oxygen saturation, but showed a distinct inverse correlation with orthophosphate concentration.

The ammonia nitrogen concentration remained low at AW1 throughout the sampling period (range 18-96µg l^{-1}) with only a small increase in spring (Fig 2b). At AW2, ammonia concentration was very much higher (range 77-1860µg l^{-1}) with a very rapid increase in March of each year followed by a moderately slow decline throughout the summer. This peak was associated with the onset of a decline in oxygen and nitrate concentrations which provide evidence that although most of the ammonia must have originated directly from allochthonous sources (such as increased sewage flow and defoliation from the surrounding areas), some resulted from bacterial reduction of nitrate. The ammonia concentration in GW showed a similar seasonal pattern at both sites, and was roughly similar to AW2, although the seasonal pattern was not so clearly shown.

In both Allander and Glazert Waters (Fig 2c), silica concentrations followed a cyclic seasonal distribution, with high winter values being reduced in spring followed by a gradual increase in summer and a moderate decline in autumn before recovering in winter.

Orthophosphate phosphorus in Allander and Glazert Waters (Fig 2d) was low in winter (10-25 μg^{-1}), but increased steadily to a maximum in summer (55-107 µg l^{-1}). Autumnal orthophosphate content was low in GW1, moderate in AW1 and GW2 and high in AW1.

Algal communities of Allander and Glazert Waters

A total of 106 species of algae was recorded during the course of the 21 months investigation (Table 2). The greatest species richness was shown by diatoms (58), followed by Chlorophyceae (20), Cyanophyceae (15), Chrysophyceae (6), Euglenophyceae (4), Dinophyceae (3) and Cryptophyceae (2). Filamentous Chlorophyceae, viz. *Oedogonium*, *Stigeoclonium* and *Cladophora* were the main contributers to chlorophyll *a* in these communities.

Jaccard's coefficient showed high similarity between algal communities. A comparison between different stations indicated greatest similarity between Allander Waters (AW1 and AW2) and between Glazert Waters (GW1 and GW2). A lower similarity was observed when all four stations were compared.

Phytoplankton community The algal flora of this community was very similar to the epiphytic and epilithic flora. Motile Chlorophyceae, such as *Chlamydomonas*, *Platymonas*, *Pteromonas*, *Carteria* and *Gonium* were present in AW1 and AW2 and GW1 during late spring and in October, but totally

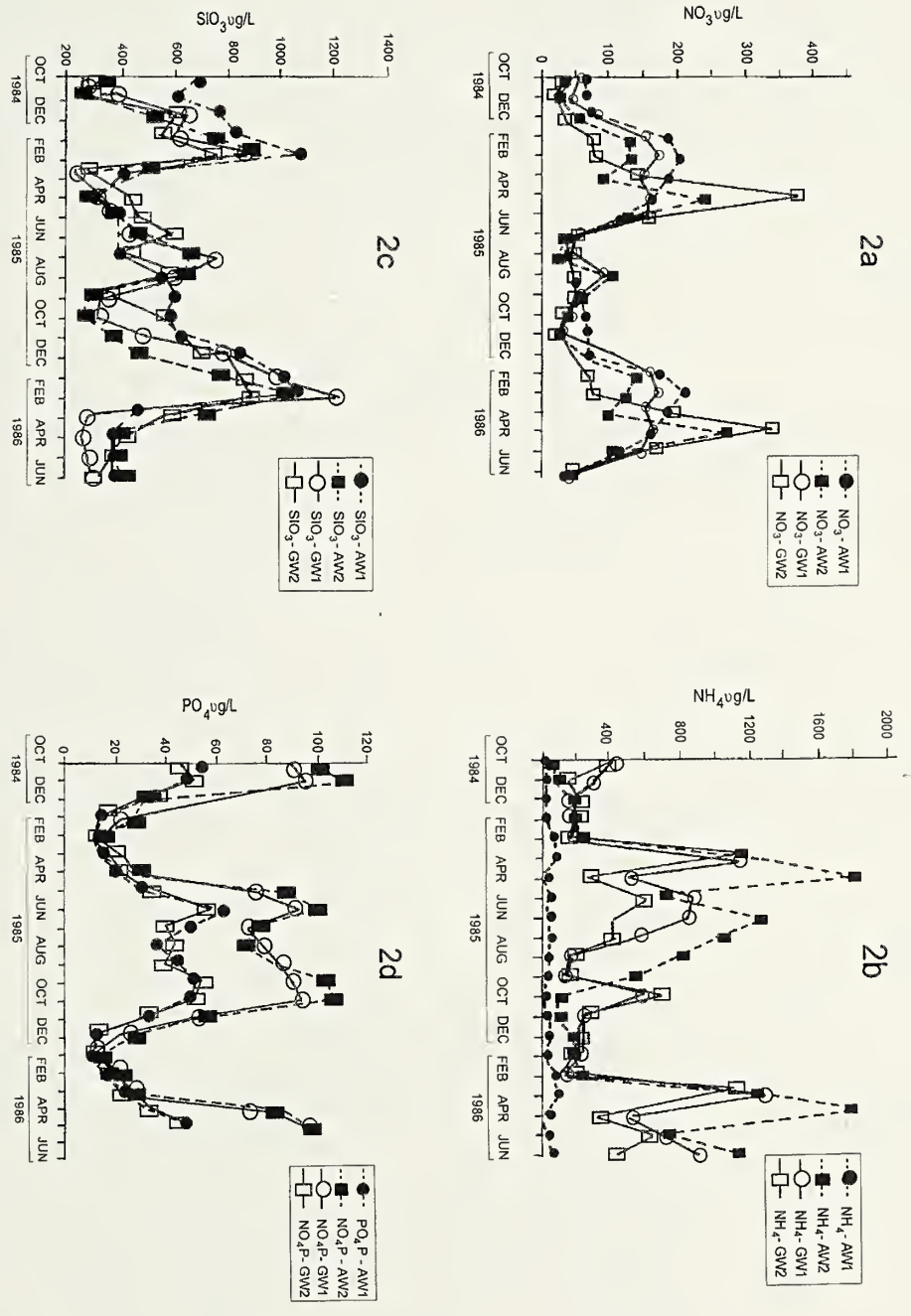

Fig. 2 Monthly records at the four sites (AW1 & 2; GW1 & 2) for a) nitrate, b) ammonia, c) silica and d) phosphate.

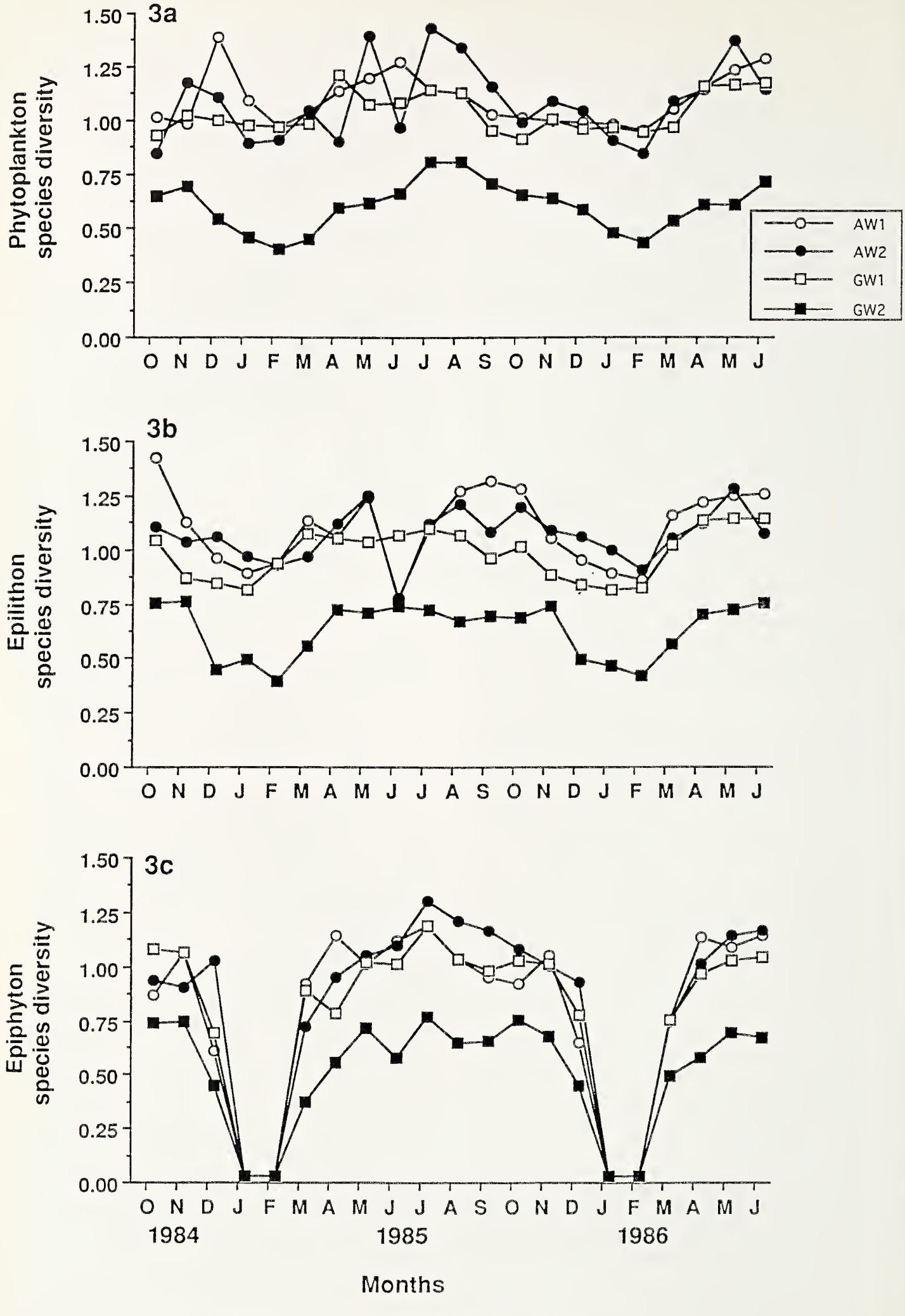

Fig. 3 Monthly records at the four sites (AW1 & 2; GW1 & 2) for species diversity: a) phytoplankton, b) epilithon and c) epiphyton.

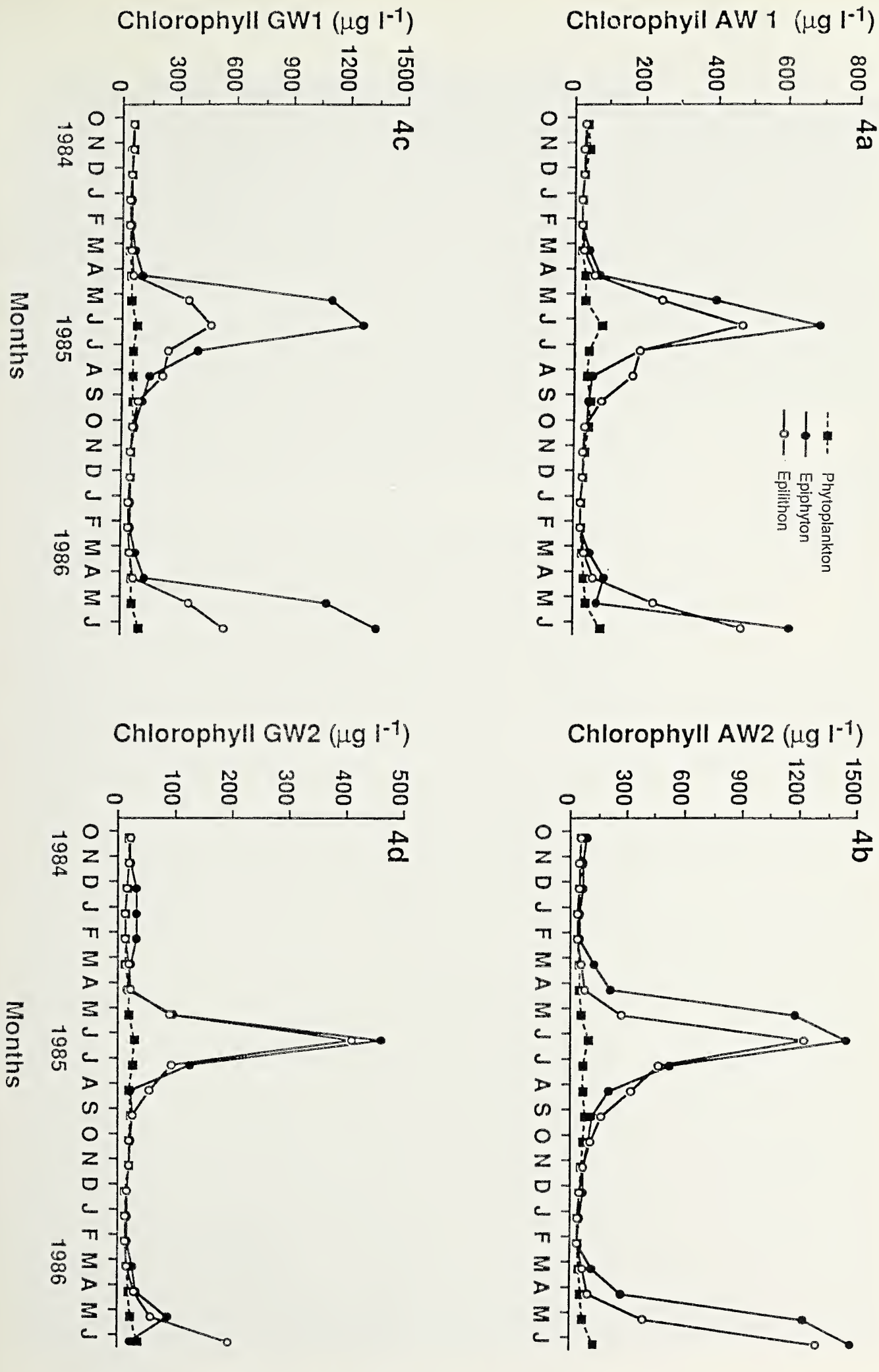

Fig. 4 Monthly records at the four sites (AW1 & 2; GW1 & 2) for chlorophyll in the three components: phytoplankton, epiphyton and epilithon.

Lime Seedling
Tilia x europaea 1997 seedling,
May, palmate cotyledons,
next leaves budding.

photo: Norman Grist

Lime Seedling
Tilia x europaea 1997 seedling,
July, one cotyledon remains,
next true leaves neither
palmate or cordate

photo: Norman Grist

Barklouse
Graphopsocus cruciatus
A common Lothain's Barklouse.

photo: B. Knoflach

A

B

C

D

E

F

Table 2. List of algal species recorded in Allander & Glazert Waters of River Kelvin between October 1984 and June 1986.

Taxon	Site			
	AW1	AW2	GW1	GW2
Bacillariophyceae				
Centrales				
Melosira varians Ag.	+	+	+	+
M. italica Roth	+	+	+	
M. crenulata Kutz.	+		+	
M. granulata (Ehr.) Ralfs	+	+	+	+
Cyclotella comta (Ehr.) Kutz	+	+	+	+
C. meneghiniana Kutz.	+	+		
C. stelligera Cl. & Grun.	+		+	
Stephanodiscus astraea (Ehr.) Grun.	+	+	+	+
Pennales				
Tabellaria fenestrata var. *asterionelloides* Grun.	+	+	+	+
T. flocculosa (Roth) Kutz.	+	+	+	
T. binales (Ehr.) Grun.	+			
Asterionella formosa Hassall	+	+	+	
Fragilaria constuens (Ehr.) Grun.	+	+	+	+
Synedra ulna (Nit.) Ehr.	+	+		
S. acus Kutz.		+	+	+
Meridion circulare (Grev.) Ag.	+	+	+	+
Amphipleura pellucida Kutz.	+	+		
Navicula cuspidata Kutz.	+	+	+	+
N. elegans Wm. Smith	+	+	+	
N. cocconeiformis Greg.	+	+		
N. placentula (Ehr). Kutz	+	+	+	
Nitzschia linearis Wm. Smith	+	+	+	+
N. sigma (Kütz.) Wm. Smith	+		+	
N. denticula Grun.		+		
N. acicularis (Kütz.) Wm. Smith	+	+	+	
N. palea Grun.		+	+	
Hantzschia amphioxys (Ehr.) Grun.		+	+	
Eunotia exigua (Bréb) Rabh.	+	+	+	
Pinnularia divergentissima (Grun.) Ralf.	+	+	+	+
P. viridis Ag.		+		
P. stauroptera (Grun.) Rabh.	+	+		
Amphora ovalis Kutz.	+	+	+	+
A. veneta Kutz.		+	+	
Cymbella prostrata (Berk.) Brun.	+		+	
C. ventricosa Ag.		+	+	
C. hybrida Grun.		+	+	
Gomphonema acuminatum var. *coronata* Rabh.	+	+	+	+
G. intricatum Kutz.		+		
G. parvulum Kutz.		+	+	
Cocconeis pediculus Kutz.	+	+	+	+
C. diminuta Pant.			+	+
Caloneis silicula (Ehr.) Cleve	+	+		
Mastogloia smithii var. *lacustris* Grun.		+	+	+
Surirella biseriata Bréb.	+	+	+	+
S. ovata Kütz.	+	+		
S. ovata var pinnata (Wm. Smith) Bréb.	+	+		
Achnanthes lanceolata (Bréb). Grun.	+	+	+	+
A.brevipes Ag.	+		+	
A. depressa (Cleve) Hust.	+		+	
Gyrosigma kutzingii Grun.	+	+	+	+
Rhoicosphenia curvata (Kutz.) Grun.	+	+	+	
Stauroneis prominula (Grun.) Hust.	+	+	+	
Denticula tenuis Kütz.		+	+	
Epithemia cistula Ralfs.	+		+	
Diatoma hiemale (Lyng.) Heiberg	+		+	
Ceratoneis arcus (Ehr.) Kütz.	+	+	+	+
Cyanophyceae				
Coelosphaerium kuetzinglianum Nag.	+	+	+	+
Stichosiphon regularis Geit.	+		+	+
Oscillatoria agardhii Gom.	+	+		+
Oscillatoria sp.	+		+	
O. limnetica Lemm.	+	+		
O. splendida Grev.	+			
Leptolyngbya fragilis (= *Phormidium fragile*) Gom.				+
Raphidiopsis curvata Fritsch	+		+	
Anabaena spiroides Kleb.			+	
A. inequalis (Kütz.) Born et Flah	+		+	
Scytonema sp.			+	+
Lepolyngbya gloeophila (= *Plectonema gloeophilum*) Borzi			+	+
Anabaenopsis circlaris (G.S. West) Wolosz and Miller	+			
Spirulina major Kütz.	+		+	
Pseudanabaena acicularis (= *Phormidium arcuata*) Skuja			+	
Chlorophyceae				
Chlamydomonas sp.	+	+	+	
Platymonas sp.				
Pteromonas sp.	+	+	+	
Carteria sp.	+	+		
Gonium sp.			+	
Scenedesmus sp.	+	+	+	+
Closteriopsis longissima Lemm.	+	+	+	+
Closterium moniliforme (Bory) Ehr.	+	+	+	+
C. acutum var. variabile (Lemm.) Krieg.	+	+	+	
C. corum Bory	+	+	+	
Staurastrum capitulum Breg.				
S. ciugulum (W & G.S. West) G.M. Smith	+	+	+	
Cosmarium costatum W & G. S. West	+	+	+	+
Netrium sp.			+	
Hormidium sp.	+	+		
Oedogonium sp.	+	+	+	+
Mougeotia sp.	+	+	+	
Stigeoclonium sp.	+	+		
Microthamnion sp.	+	+		
Cladophora sp.	+	+	+	
Euglenophyceae				
Englena acus Ehr.	+		+	+
E. limnophyla Lemm.		+		
Phacus onyx Pochmann			+	
Trachelomonas hispidata Lemm.	+		+	+
Dinophyceae				
Peridinium sp.			+	
Gymnodinium sp.			+	
Ceratium hirundinella Bergh.	+	+		
Chrysophyceae				
Ochromonas sp.	+		+	
Synura sp.	+	+	+	+
Mallomonas sp.	+			
Chrysococcus sp.	+			
Bumilleriopsis sp.	+			
Dinobryon divergens Imhof	+		+	
Cryptophyceae				
Cryptomonas sp.	+	+	+	+
Rhodomonas sp.		+	+	

absent from GW2. On the other hand, euglenoids (*Euglena acus, Phacus onyx* and *Trachelomonas hispidata*) were present in AW2 and GW2 and with the exception of *Euglena limnophyla*, absent from AW1. *Cryptomonas* was unique to the phytoplankton and was found at all four stations. Blue-green algae, particularly *Oscillatoria* sp., *Coelosphaerium kuetzingianum and Anabaena inequalis* were abundant in the spring bloom and again in late autumn. Diatoms were found at all four stations, and a significant number of species shared community similarity with epiliths and epiphytes. *Stephanodiscus*, *Cyclotella* and *Melosira* were recorded as plankton only at times during summer. They were also found mixed with epiphytic and epilithic algae during late summer and autumn.

The species diversity was calculated from Log_{10} data for each algal community at each site (Fig 3a). Diversity ranged between 0.8 and 1.4 at all sites except GW2, where the range was 0.4 to 0.8. In all cases diversity was higher in summer than in winter, although this pattern was less clearly seen at GW1.

The phytoplankton species richness showed the number of species to vary from 15 to 42 and all four stations showed uniform summer maxima. The plankton estimated as chlorophyll *a* was lower than that of the epilithic and epiphytic algal communities (Fig 4). The chlorophyll degradation

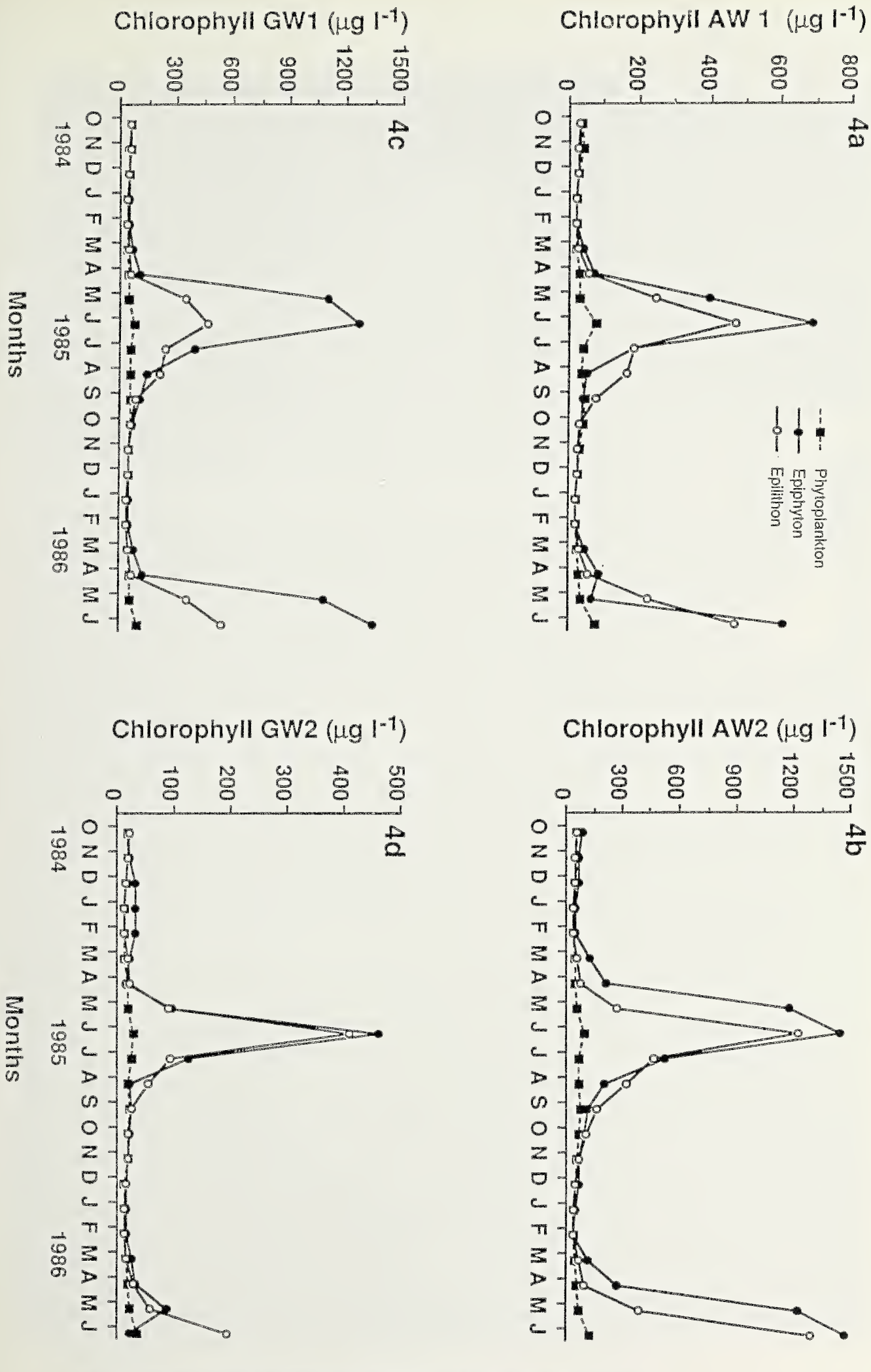

Fig. 4 Monthly records at the four sites (AW1 & 2; GW1 & 2) for chlorophyll in the three components: phytoplankton, epiphyton and epilithon.